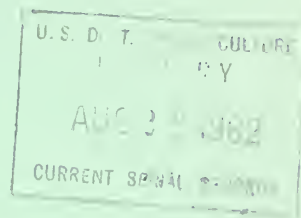


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A FIELD TEST OF POINT-SAMPLE CRUISING

by

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E R R A T A

In A FIELD TEST OF POINT-SAMPLE CRUISING by Albert R. Stage,
Intermountain Forest and Range Experiment Station Research Paper 67,
please make the following corrections:

Page 7, Table 1. In the column headed "Std. error of mean HDF"
change the value opposite "All obscured" to .048.

Page 10, paragraph 2, line 5. Change to, "Thus a tree 0.09 foot
. . . "

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A FIELD TEST OF POINT-SAMPLE CRUISING

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BACKGROUND

The validity and usefulness of point-sampling as a timber cruising technique are well established. Grosenbaugh and Stover's (1957) report of the test of wedge-prism point-sampling compared with plot sampling in southeast Texas leaves no doubt that this technique, properly applied and with results properly compiled, can be used effectively for reliable timber surveys. Their discussions of procedures and methods of analysis indirectly indicate reasons why some earlier trials of point-sampling may not have been valid tests of the technique. Further tests of different methods for applying point-sampling to other stand conditions can be patterned after their study to good advantage.

Trials by Shanks (1954), Larson and Hasel (1958), Lindsey et al. (1958), and others have shown that point-sampling can yield more stand information for a given cost than plot cruises. Furthermore, Afanasiev (1958) has indicated that the point-sample may be less subject to errors when used by inexperienced crews than conventional plot procedures.

That errors can arise, however, in point-sampling while seemingly following recommended procedures has been demonstrated by Grosenbaugh (1949), Deitschman (1956), and Stage (1951). For example, a prism or angle-gauge of a factor not suited to stand conditions can introduce errors in basal-area estimates. Qualifying trees are more likely to be missed or miscounted with smaller basal-area factors. Biased plot center locations are more likely to be serious when the tree count is very low. These two considerations must be balanced in selecting the basal-area factor. Guides to appropriate prism factors for various stand diameters have been prepared for western conditions by Bell and Alexander (1957). They state that with an appropriate prism factor, one should count four to eight trees per point. Unfortunately, the data on which these recommendations are based have not been published.

Furthermore, counting fewer trees per point necessitates sampling at more points to attain the same cruise precision. Thus, certain basal-area factors may be more efficient than others in obtaining stand information. Few data are available for evaluating relative efficiency basal-area factors in obtaining stand information.

The wedge-prism is the most popular device for point-sampling in the United States--perhaps because of its simplicity and convenience. Various gadgets and techniques have been devised following Bruce's (1955) suggestions for rotating the prism to correct for sloping sight lines. On the other hand, Grosenbaugh (1958) recommends correcting for slopes by applying a single correction to the entire point-sample based on an average slope perpendicular to the contour.

In rough country where plot surfaces are not simple inclined planes, the mean slope estimate by nature cannot be very objective. Slope adjustments on a tree-by-tree basis are critical only for marginal or near-marginal trees. Such trees can be checked under either system with equal ease by using a marginal tree computer (Stage, 1959).

In most tests that have shown good results in using wedge-prisms, marginal or doubtful trees have been carefully checked by measuring their diameter and distance from the sample point. However, the usual recommendation for extensive cruises is to tally such trees separately and add half of their total to the sample. Whether an optical illusion might cause the ratio of "ins" to "outs" to be other than 50-50 has never been checked so far as I know.

In addition to testing techniques of application, a study of point-sampling should also provide information helpful in designing timber cruises to meet specified limits of accuracy. By relating coefficients of variation for point-sampling to those for conventional plot procedures, the experience data from the older techniques can be made available for designing point-sample cruises.

OBJECTIVES

This study was a joint effort of the Intermountain Forest and Range Experiment Station and Region 1 of the U.S. Forest Service. Information obtained from it will be used to establish guidelines for point-sampling in the northern Rocky Mountains.

Specific objectives of the study were three-fold:

1. To determine the prism factors most appropriate for our stand conditions.
2. To isolate, as far as feasible, the sources of error that occur in using a prism of other than optimum factor for a particular stand condition.
3. To provide data on the relative numbers of point-samples needed to achieve the same precision of basal-area estimate as a given number of 1/5-acre plots.

PERSONNEL AND TRAINING

Forest Survey and Forest Management inventory crews made the variable plot estimates in conjunction with establishing regular sample plots to Intermountain Forest Survey standards. This study procedure somewhat restricted the methods of measurement and the distribution of samples by forest type. However, the information could not be so economically obtained otherwise.

Field crews were trained at week-long schools held by Forest Survey and Region 1 Division of Timber Management in preparation for their plot establishment work.

FIELD DATA

The fixed area plot data consist of the diameters measured by diameter tape to 1/10-inch limits of all trees on two concentric plots established at each location. Trees 11.0 inches and larger were tallied on a 1/5-acre circular plot. Trees between 5.0 and 10.9 inches were tallied on a 1/50-acre plot.

The point-sample consisted of a count with each prism of all trees 5.0 inches and larger about the fixed-area plot center. It was intended to use three prisms having basal area factors of 10, 15, and 25, but, not all crews had complete sets. Trees clearly within the "plot" were recorded separately from marginal trees. The latter were recorded as being visible from plot center to the tree clear or obscured by brush or other trees. In addition, slope percent, slope distance, and d.b.h. were recorded for the first two marginal trees encountered with each prism on each plot.

Slope adjustment of the prism point data was made on a tree-by-tree basis. Bell and Alexander's (1957) method of determining prism rotation by an Abney level was used. The Abney was sighted at d.b.h. and the bubble clamped. Then the Abney was turned at right angles, and the prism held on top of the Abney so that the line of sight was perpendicular to the face of the prism with the level bubble centered.

ANALYSIS

Prism Calibration

A majority of the prisms used in this test had been factory calibrated to an even basal-area factor or to an even prism diopter. However, a few uncalibrated prisms were also used. All prisms were calibrated by the author to establish values for the uncalibrated prisms and to check the calibration on the others. The calibration procedure did not require movement of the prism to attain coincidence of the deflected image with a point on the true image. By using this procedure, personal bias is eliminated. Personal differences in prism calibrations have been noted by several authors. However, until these differences can be demonstrated as constant and persistent under varying conditions, an objective procedure such as that used in this study seems preferable.

A transparency of a fine white cross against a black field was projected on a smooth screen about 25 feet distant. A horizontal line through the image of the cross was drawn on the screen, and the location of the cross marked on the line.

Each prism to be calibrated was placed 6 to 8 inches in front of the projector lens. The prism was mounted so that the knife-edge was perpendicular to the light beam, and the viewing edge in the middle of the light beam. Thus, two images of the cross appeared on the screen, the direct image from the portion of the light beam which passed over the prism and the deflected image from the light passing through the prism. The prism was rotated until the deflected image fell on the horizontal screen on the target. Then the prism was turned to obtain a minimum deflection of the image. The position of the deflected image was marked on the screen, and the procedure was repeated with the prism reversed. The distances (w) to the right and left deflected images from the true image were precisely measured and averaged. Then the distance (d) from the true image to the center of the prism was carefully measured. This process was repeated twice for each prism so that four deflection measurements were obtained.

The ratio of distance to target (d) to deflection distance (w) or d/w has been called Q by Grosenbaugh (1958) and is related to basal-area factor by the equation:

$$\text{BAF} = \frac{43,560}{(Q + \sqrt{Q^2 + 1})^2 + 1}$$

Basal-area factors were computed from the two sets of measurements for each prism. The lower of the two determinations for each prism was used as the calibration for that prism since it represented the minimum deflection.

The new calibrated values for the prisms were about 1 percent higher than the values specified by the manufacturer. Consistency of the pairs of calibrations left little doubt that a real difference existed. However, it is not clear whether the difference is the result of differences in calibration procedure or in the specifications to which the prisms were manufactured.

The deflected image, of course, showed considerable chromatic aberration. The brightest (yellow) portion of the spectral image was used as representing the position of the deflected image. The difference in calibration depending on which portion of spectrum was used amounted to about a 1-percent difference in the basal-area factors obtained. This fact suggests one possible source of personal bias--persons who respond differently to the different energy bands in the spectrum could obtain somewhat different calibration values. Likewise the colors of the tree trunk and the background could affect the calibration.

Marginal Tree Measurements

Field Test

Marginal tree measurements were intended to supply information pertaining to the following questions:

1. Is the assumption that one-half of the count of marginal trees should fall inside the plot unbiased?

2. What order of precision can be attained using a hand-held prism without optical magnification? (For this purpose, caliper measurements of tree diameter would have been preferable in order to remove the component of variation due to elliptical tree cross sections. However, the organization of the study precluded their use.)
3. Do prisms of different basal-area factors vary in precision attainable?
4. Is the method of adjusting for slope unbiased?

Grosenbaugh (1958) has demonstrated that diameters measured by tape give an unbiased estimate of $1/K$ times the average distance at which a tree will qualify for counting with point-sampling. Thus, inclusion of elliptical trees should not bias the marginal tree data, although they will increase its variation.

Grosenbaugh has called the ratio, horizontal distance in feet divided by tree diameter in inches, the horizontal distance factor (HDF); this factor equals $24K$. Figure 1 provides a visual representation of various horizontal distance factors as viewed through a prism for which the limiting HDF is 1.739 (basal-area factor of 25).

HDF ratios were computed for each marginal tree. Then these ratios were adjusted^{1/} to a common base as though a prism having a basal-area factor of 25 had been used throughout the test. On the 801 plots measured, only 133 trees were considered to be doubtful for counting. Of these, 24 were discarded from the analysis because their measurements did not carry enough significant digits.

The marginal tree data for 109 trees, summarized in table 1, show the following:

1. There is no significance to the small difference between the mean adjusted HDF's for the two prism strengths compared. However, the variance of adjusted HDF for marginal trees to which visibility was clear is relatively greater for the 10x prisms than for the 25x prisms. The hypothesis that the variances of adjusted HDF associated with the two prism factors are from the same population can be rejected with a probability of between 90 and 95 percent. This fact suggests that use of the 10x prisms is proportionally less precise than use of the 25x prisms.

$$\frac{1}{\text{Adjusted HDF}} = \text{HDF}_x \sqrt{\frac{\text{BAF}_x}{25}}$$

where $\text{HDF}_x = \frac{\text{Horizontal Distance in Feet}}{\text{Tree Diameter in Inches}}$ using prism
 x having basal-area factor = BAF_x

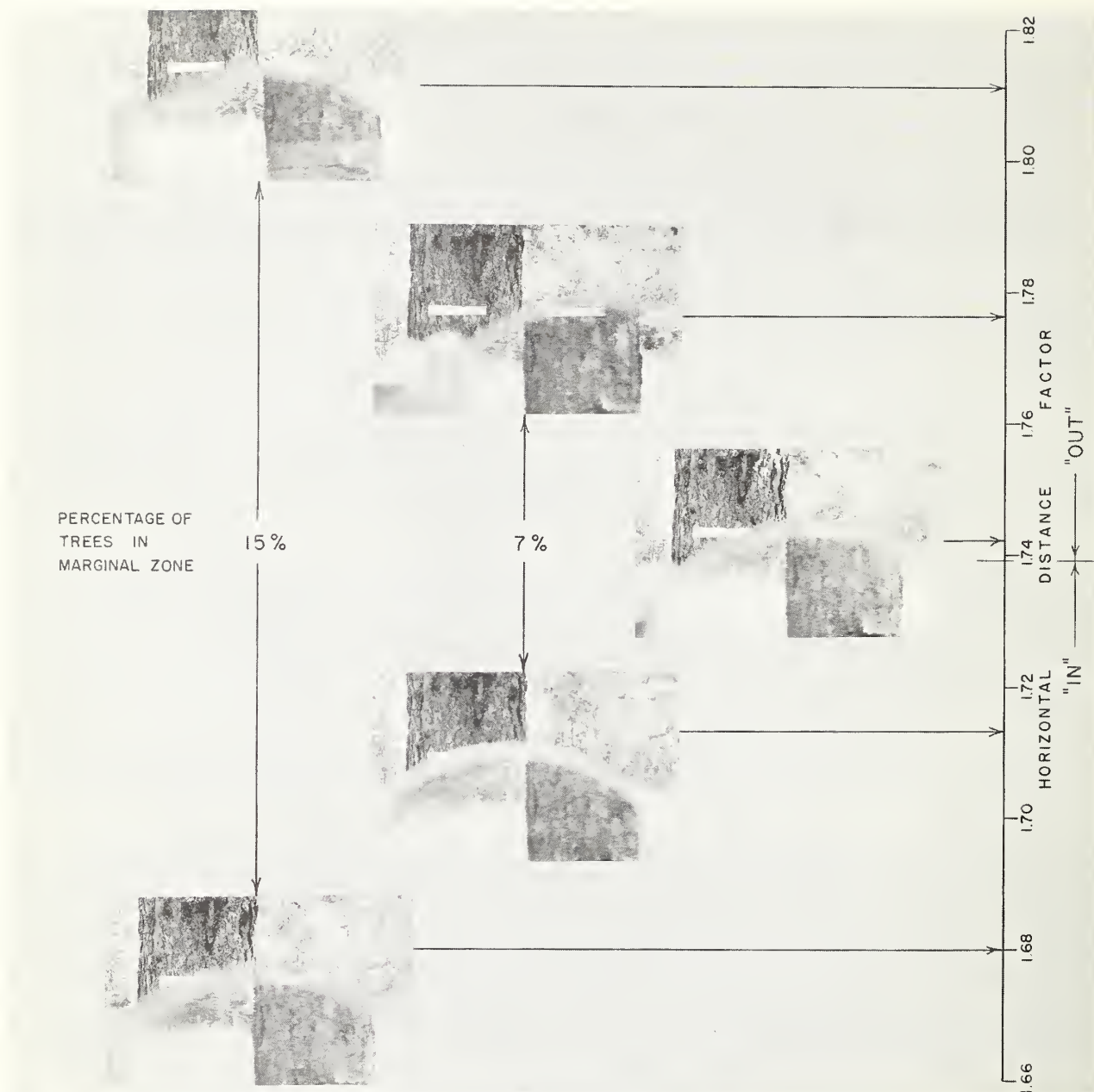


Figure 1.--Visual interpretation of marginal trees as viewed through a 25x prism for which the limiting horizontal distance factor is 1.739. Horizontal arrows indicate the actual HDF corresponding to the distance from prism to tree for each photo. Figures on the vertical arrows indicate the percentage of the actual tree count which would be within the indicated limits for marginal trees.

Table 1.--Analysis of marginal tree data comparing adjusted horizontal distance factors for prisms of two basal-area factors

Group	No. of trees	Mean adjusted HDF	Standard deviation of HDF	Std. error of mean HDF = σ_m	Percent of trees with HDF 1.739	Chi-square $\frac{1}{1}$	t = $\frac{1.739 - \text{mean}}{\sigma_{\text{mean}}}$
Clear visibility							
10x prism ^{2/}	36	1.692	0.199	0.033	72.2	6.25**	1.42
25x prism	41	1.669	.145	.023	70.7	6.24**	3.04**
All clear	77	1.680	.171	.020	71.4	13.30**	2.95*
Obscured visibility							
10x prism ^{1/}	14	1.652	.255	.068	64.3		1.28
25x prism	18	1.625	.288	.068	72.2		1.68
All obscured	32	1.637	.270	.0948	68.8		2.12*
All trees	109	1.667	.205	.020	70.6		3.60*

1/ Chi-square test for deviation from an assumed ratio of 1:1.

2/ Data for 10x prisms scaled so as to be on same base as 25x prism data.

* = significant at 95-percent level of probability.

** = significant at 99-percent level of probability.

- The mean HDF of marginal trees (1.680) is significantly less than the limiting value of 1.739. This fact is also demonstrated by the observation that 71 percent of the marginal trees were within the "plot" boundaries. If we assume that the mean HDF of clear marginal trees represents the plot boundaries as actually established, the average plot area would be reduced to 93.3 percent of its proper size.

Correction for slope was checked by plotting HDF over inclination of the line of sight to the tree (fig. 2). The plotted points show the range of HDF values obtained. The horizontal solid line is drawn at the limiting HDF of the adjusted data. Some of the variation of these HDF's is due to the inclusion of elliptical trees. An indication of how ellipticity affects such data is shown by the dashed line in figure 2. This line represents the limiting HDF for a population of elliptical trees whose smaller diameter is nine-tenths of the larger diameter, and which are located on a 70-percent slope with their long axes perpendicular to the contour. The six crosses indicate the points that would represent six trees from such a population equally spaced in a quadrant starting along the contour and extending either up or downhill. The fact that these six points are equally distributed above and below the limiting HDF for circular trees is further evidence that ellipticity introduces very little bias in the horizontal distance factor.

In spite of the possibility of slope-oriented elliptical trees introducing a negative regression of HDF on slope of sight line, no such trend could be detected in the data. Furthermore, the variation about the average appears to be uniform throughout the range of slopes. Thus, sloping ground does not

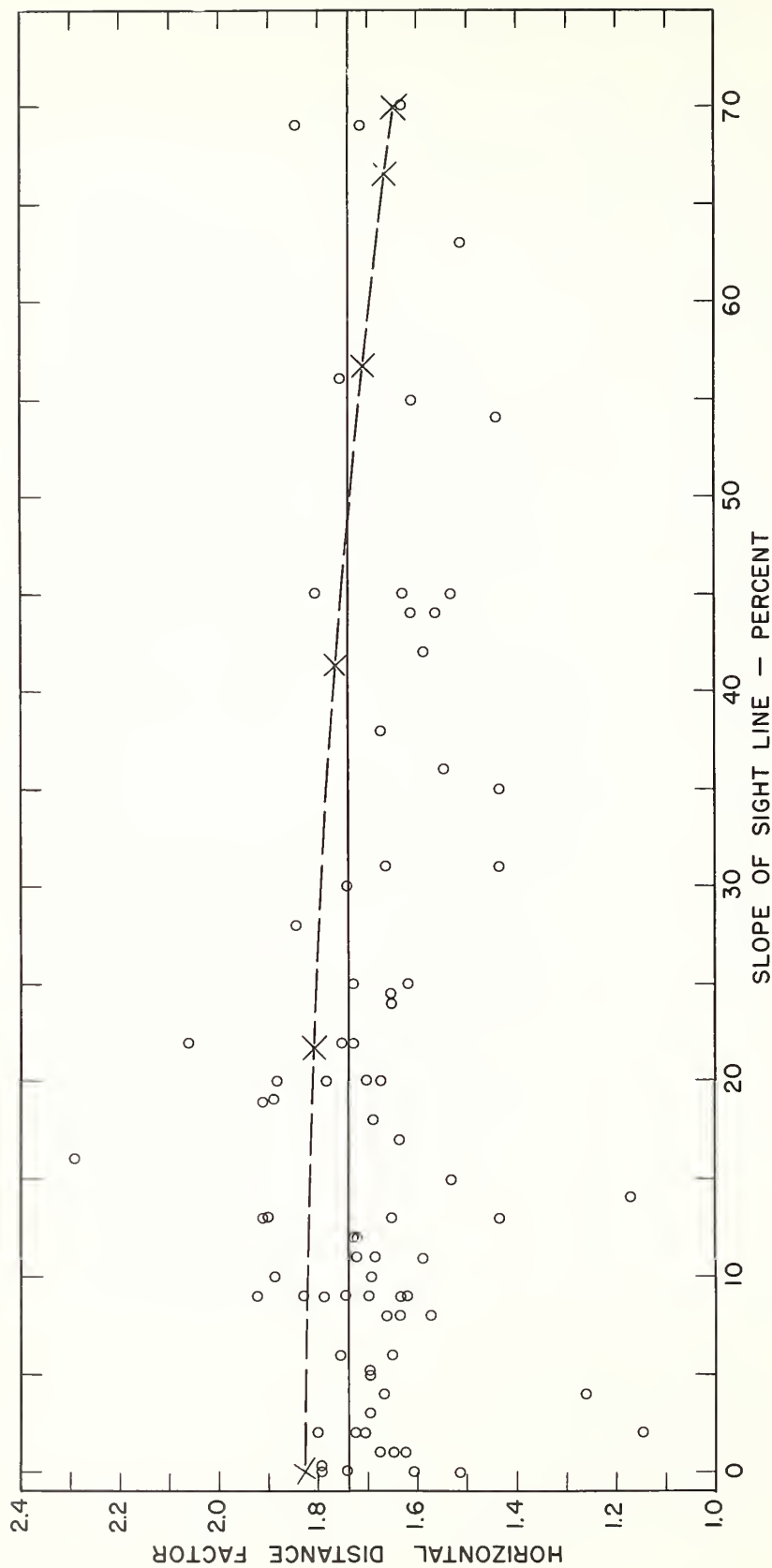


Figure 2.--Trend of horizontal distance factors to marginal trees is horizontal with respect to slope of sight line. Solid line indicates limiting value to qualify for counting. Dashed line indicates the same limit for elliptical trees ($e = 0.9$) growing on 70-percent slopes with their long axis perpendicular to the contour.

decrease materially the precision with which a prism can be used with the previously described slope adjustment technique.

Decisions on marginal trees must be made at greater distances with prisms of lower basal-area factors. To test whether sheer distance affected the relative accuracy, the adjusted HDF's were plotted over slope distance to the tree. Again the trend is horizontal with approximately uniform variance. The 10x prism showed a wider spread than the 25x throughout the range of distances.

A necessary corollary of the observation that HDF is dispersed uniformly about a horizontal line with respect to distance is that there will be a negative trend as tree diameter increases (see fig. 3). Its regression coefficient is significantly different from zero at the 95-percent level of probability. This negative trend could arise from either of two measurement sources in these data: one, an error in the use of the prism; and the other an error in the control measurement.

1. With regard to the former, the crews were instructed to keep the top edge of the prism even with the breast-height point on the trees. Thus, when the prism is rotated to correct for a 40-percent slope, the deflected image of the side of the tree differs in level from the d.b.h. point by 0.20 times the tree diameter. The number of comparisons with points above b.h. should equal those with points below b.h. However, greater rates of taper below breast height than above would cause more marginal trees to fall within the limit than outside. This effect would be more serious with larger trees than with small ones.
2. As to the latter source, errors in taped diameters (such as a sagging tape, or irregularly shaped cross sections) tend to overestimate diameter and thus give a lower HDF. Such errors would be more serious on large trees than small ones.

The latter source would introduce no bias in the basal area estimate based solely on the tree count obtained by the prism. The effect of the first source could be minimized by comparing the sides at a level such that the average of the high and low images is slightly above the true breast height.

Photo Judging Test

The field data have demonstrated that the average HDF of the marginal trees does not coincide with the theoretical limits. Study of a series of photographs similar to those in figure 1 indicates why this discrepancy may have occurred.

Eleven photographs had been taken of a tree viewed at the edge of a calibrated prism. Each photograph was taken at a slightly different distance from the tree for HDF's ranging from 1.659 to 1.834. The limiting HDF of the prism was 1.739. At each setting of the prism, a transit was centered over the prism, and the horizontal angle turned from one side of the tree to the other at the marked breast height. The HDF for each photograph was derived mathematically from this measured angle. The eleven photographs were arranged at random on a panel.

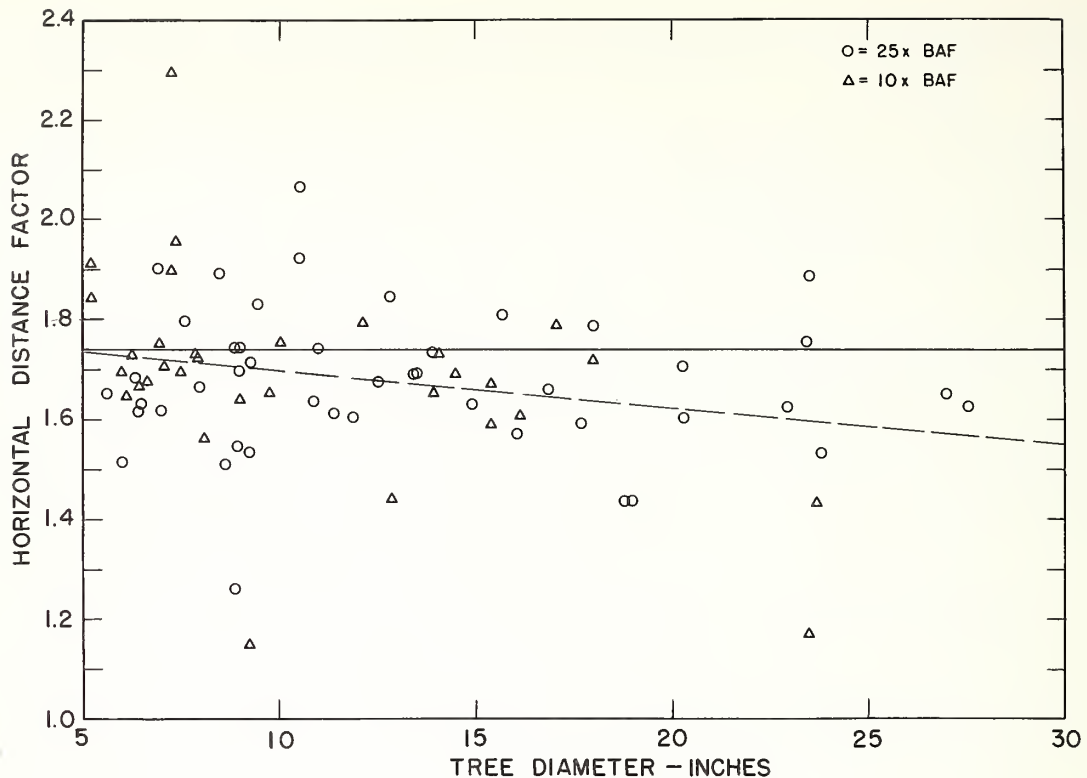


Figure 3.--Dashed line indicates the trend of marginal tree horizontal distance factors with tree diameter. Regression coefficient is significantly different from zero at the 95-percent level of probability.

Students of the University of Idaho mensuration class plus a number of other interested persons were asked to match photographs. Each person matched a sample photo with one from the panel which was "out" to an extent equivalent to that by which their sample tree was "in" or vice versa. The results of 86 such matchings with seven different sample photos show that there is a pronounced tendency to equate trees that are well within their "plot" with trees that are just barely out. Seventy-one percent of the pairings were in this direction, 19 percent matched the trees evenly, and 10 percent matched trees further out with trees just inside the limit. The mean HDF of the pairings was less than the limiting value. The t-value for the difference was 1.7, which corresponds to a probability well beyond the usual thresholds of significance.

From a theoretical standpoint, these results are just opposite to what would be expected. A 10-inch tree that is exactly marginal at 17.39 feet would have images that overlap by a visual angle of 26.4 seconds at 17.30 feet. To obtain a lack of overlap of an equal angle, the tree would have to be 17.49 feet away. Thus a tree 0.9 foot inside the boundary would appear to correspond to one 0.096 foot out. However, visual matching of photographs and the results of field measurements to actual marginal trees show that the balance is in the opposite direction. Apparently marginal trees that should not be counted are

more easily determined as being out than the converse. Thus, the assumption that one-half of the tally of marginal trees ought to be counted cannot be relied upon as unbiased.

Plot Basal Area Estimates

Comparison of Means

The comparisons of point samples to plot samples were intended to test one technique of using prisms for general timber cruising purposes. That is, the prism was to be the only means of estimating basal-area. Doubtful trees were not checked for counting other than optically through the prism. However, doubtful trees were recorded separately and counted as one-half the usual value. Thus the precision is not comparable to tests such as those of Grosenbaugh and Stover (1957) or Keen (1950) in which marginal trees were carefully checked by taped distances.

Plot data were classified (1) into stand strata composed of three stocking classes, two size classes, and four species groups, and (2) into ten diameter groups. The stand strata were determined by the type in which the plots fell and not necessarily by the plot data. This procedure avoids the skewed distribution of small plots with respect to larger ones at the extremes of density when grouped according to their respective stockings, as noted by Grosenbaugh and Stover (1957).

The strata were defined as follows:

Stocking classes:

Well = 70 percent + crown closure
Medium = 40-69 percent crown closure
Poor = 10-39 percent crown closure

Stand-size classes:

Sawtimber = more than 1,500 bd. ft. in trees 11"+ d.b.h.
Poletimber = stands failing to meet sawtimber specifications but at least 10-percent stocked with 5"+ d.b.h. trees and with at least 5 percent in poletimber (5"-10.9" d.b.h.) trees.

Species groups:

Ponderosa pine
Douglas-fir and western larch
Lodgepole pine
Western white pine (including western redcedar, hemlock, and grand fir)

The data were compiled by species groups, but differences between species were insignificant except as could be explained by size or stocking.

Differences between prism and fixed-plot estimates of basal area are expressed as a percentage of the latter in table 2. These data show a tendency to underestimate basal area in stands of sawtimber size, especially when the stocking is high. This trend is evident in the data for both basal-area factors but is more pronounced with the 10x prism. On the other hand, there is a consistent tendency to overestimate basal-area of poletimber stands with the 25x prism.

Table 2.--Percent differences between prism and fixed plot basal-area estimates with their associated standard errors^{1/}

Group	Stocking class			All stocking
	Well	Medium	Poor	
	<u>Percent</u>			<u>Percent</u>
25x prism ^{2/}				
Sawtimber	-11.0 \pm 3.6**	-2.3 \pm 3.7	-7.6 \pm 8.0	-5.5
Poletimber	+14.5 \pm 6.6*	+2.3 \pm 4.7	+18.2 \pm 20.5	+7.9
All sizes	-6.8 \pm 3.3*	-1.1 \pm 3.0	+8.7 \pm 7.2	-3.1 \pm 2.2
10x prism ^{3/}				
Sawtimber	-25.4 \pm 5.9**	-16.1 \pm 4.4*	^{4/} +17.6 \pm 9.3	-21.0
Poletimber	-0.1 \pm 7.4	+3.1 \pm 11.9	^{4/} +41.7 \pm 20.4	+2.7
All sizes	-22.6 \pm 5.6**	-14.5 \pm 4.3**	-14.7 \pm 8.8	-18.7 \pm 3.4**

^{1/} Standard errors were not obtained for size classes independent of stocking.

^{2/} Data from 524 plot comparisons.

^{3/} Data from 299 plot comparisons.

^{4/} Consists of only seven pairs of observations.

** = Difference significant at 99-percent level.

* = Difference significant at 95-percent level.

Data comparing both prism factors to the fixed-area plot are available on 299 plots. Their over-all means are as follows:

<u>Means of Estimation</u>	<u>Mean Basal-Area--Sq.ft./acre</u>
1/5-1/50-acre plot	114.3
25x prism	113.7
10x prism	93.0

The difference between the means for the two prism strengths amounted to 18 percent of the fixed plot estimate of basal-area. These data, compared to a common base, show that for the types encountered the 25x prism was better suited than the 10x to the conditions of size and stocking.

Figure 4 shows the percentage difference between the prism and plot estimates by mean diameter of the trees on the fixed-area plot. The trends of the two prism estimates are parallel. The 25x prism means exceeded the plot means to a greater degree in stands of small diameter trees than did the 10x data. Conversely, the 10x prism resulted in more serious underestimates in stands of large diameter trees than did the 25x prism.

Underestimates of basal-area are readily ascribed to trees overlooked in dense stands or at great distances from the sample center, and to the biased treatment of marginal trees. However, the overestimates that occurred in stands of small diameter are not so readily understandable. Several possibilities can be mentioned:

1. The hand-held prisms may not have been kept directly over plot center. If the prism were between the tree being viewed and plot center, an overestimate of basal-area would result which would be more noticeable in stands of small diameter.
2. Bias in plot center location results if plot center locations at or very close to the position of a tree bole are rejected. This bias would cause some overestimate in basal-area at the sizes and densities encountered if the trees tended to be uniformly spaced.
3. There was positive correlation between diameter and mean stand basal-area. For comparisons in which the plots were grouped according to the mean diameter of the fixed-area plot only, it may be assumed that they were also grouped according to the fixed-plot basal-area. The overestimates in the smallest diameter classes and the underestimates in the largest classes can be explained in the light of Grosenbaugh and Stover's (1957) discussion of the distribution of small (prism) plot means with respect to larger plot means. The difference in the means can be attributed then to logical characteristics of sampling procedure and do not represent bias if the general means coincide. The 10x prism plot size was greater than the corresponding fixed plot for tree diameters of about 6 to 11 inches. In this range, the relation of prism to plot would be reversed. Thus the fixed-plot estimates exceeded the prism estimates in these diameter classes, although they fall in the lower part of the distribution.

Relative Efficiency for Cruising

Forty-two percent as many trees per plot were tallied with the 25x prism as with the 1/5-to 1/50-acre plot design. For the 10x prism, 18 percent more trees were tallied than with the fixed-area plot.^{2/} Over-all, the same level

^{2/} The number of trees for the prism estimate was obtained from the mean basal-area of fixed-area plot, the basal-area factor of the prism, and the number of plots. Thus, the possibility that some trees may have been missed with the 10x prism does not confound the present discussion.

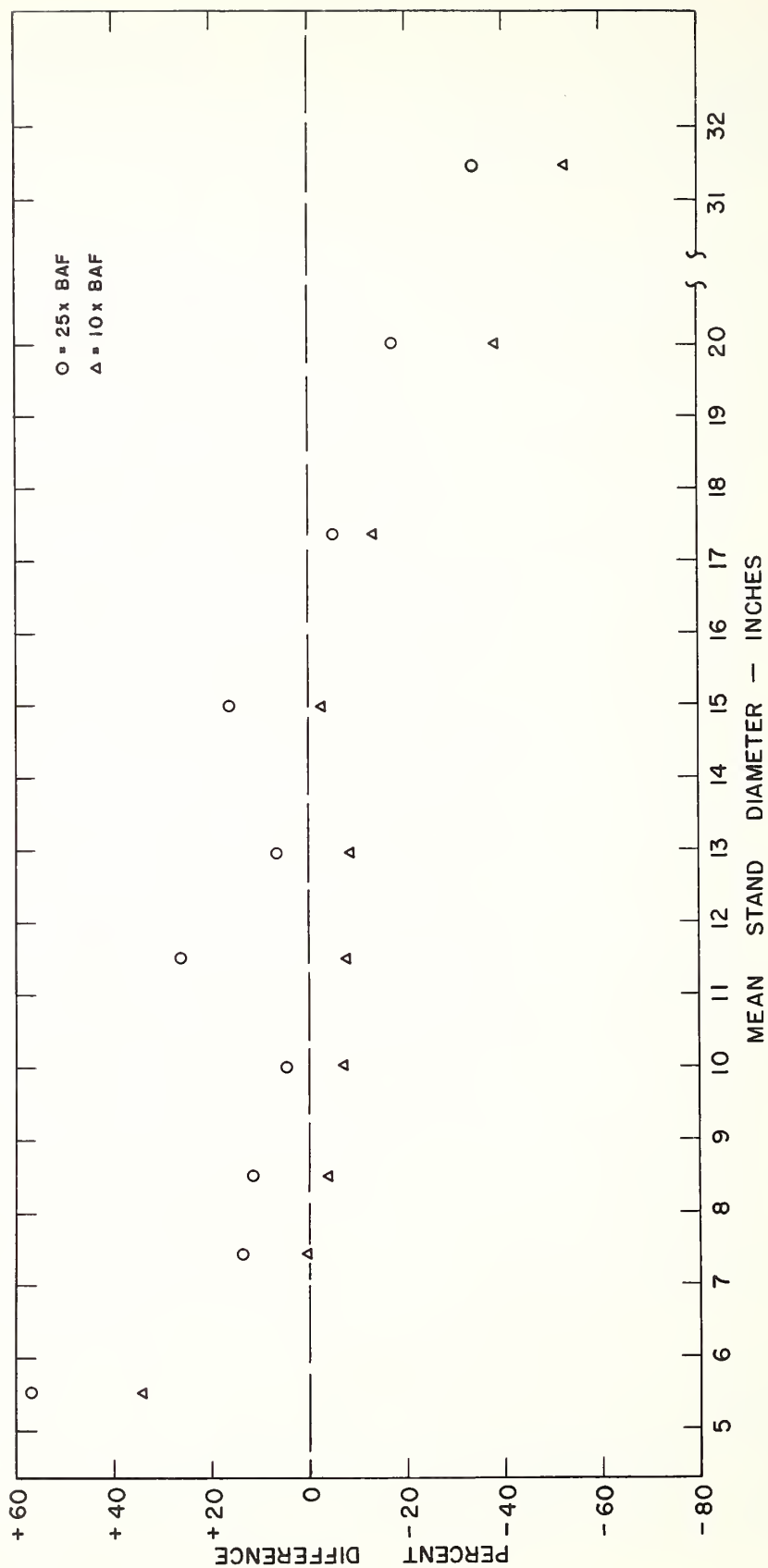


Figure 4.--Ratio of prism basal-area estimate to fixed-area plot basal-area estimate decreases with increasing mean d.b.h. of trees on the fixed-area plot for both 10x and 25x prism data.

of precision could have been achieved with fewer prism samples than with the fixed-area plots. Table 3 shows this relation by stand strata. The last column for 25x data shows that 87 percent as many prism plots would be required as with the fixed-area plots. With only 42 percent as many trees per plot, the prism estimate could achieve the same level of precision with 36 percent as many trees to consider as with the conventional plot cruise. Even in the least favorable stratum, well-stocked poletimber, the percentage is only 69. For the 10x prism data, the relative efficiency is 58 percent by number of trees.

Table 3.--Relative numbers of prism plots required to achieve precision equivalent to that on one hundred 1/5- to 1/50-acre plots for basal-area estimates by stand strata^{1/}

Group	Stocking class			All stocking
	Well	Medium	Poor	
25x prism				
Sawtimber	82	111	121	
Poletimber	161	103	80	
All sizes	83	109	107	87
10x prism ^{2/}				
Sawtimber	50	57	^{3/} 64	
Poletimber	91	89	^{3/} 246	
All sizes	41	58	63	49

1/ Equals: $\left(\frac{\text{Std. dev. prism b.a.}}{\text{Std. dev. plot b.a.}} \right)^2$

2/ The 10x prism data were obtained on only 299 of the 524 plots for which 25x prism data were obtained. The over-all coefficient of variation of the fixed-area plots was 71 percent for all plots vs. 80 percent for the 299 plots. Hence, the two prism strengths should not be compared in this table.

3/ Based on only six degrees of freedom.

The relative efficiency of the two prism strengths depends on their respective standard deviations. For the 299 plots on which both prisms were used, the square of the ratio of their standard deviations $(\sigma_{25}/\sigma_{10})^2$ is 2.03. Thus 203 25x prism plots should have a standard error of the mean equal to that of 100 10x prism plots from the same timber. However, the 25x plots would contain only ten twenty-fifths or 40 percent as many trees per plot as the 10x plots. Thus, (40 percent) (203 percent) = 81 percent as many trees would be needed when counted with the 25x prism as with the 10x prism.

Since the 10x prism requires fewer plots and the 25x prism requires fewer trees, the decision on their actual relative efficiencies must depend on time studies of the variable cost per tree tallied vs. the fixed cost of plot establishment for each prism. Such data were not obtained in this test.

CONCLUSIONS

For general use in northern Rocky Mountain forests, the prism having a basal-area factor of 25 (4.79 diopters) appears to be most generally suitable. However, for well-stocked large sawtimber, a higher basal-area factor may be even more desirable. For stands of small diameter and good visibility, such as lodgepole pine stands in Montana, the 10x prism is suitable and perhaps more efficient than the 25x prism from the standpoint of efficiency.

Marginal trees should be checked for tallying by careful measurements to avoid bias in the basal-area estimate. It is doubtful that use of a hand-held prism reduces the task of checking marginal trees as compared to a fixed-area plot procedure. However, shortcutting this job is less likely to affect the accuracy of prism data than it would fixed-area plot data. Quite satisfactory basal area estimates were obtained here without any distance measurements when the appropriate prism strength for the stand conditions was used.

It seems quite clear that either prism factor considered in this test is more efficient than the 1/5- to 1/50-acre plot from the standpoint of efficiency. Fewer plots and fewer trees per plot are necessary for prism estimates of basal area than for fixed-area plots to attain equal statistical precision.

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